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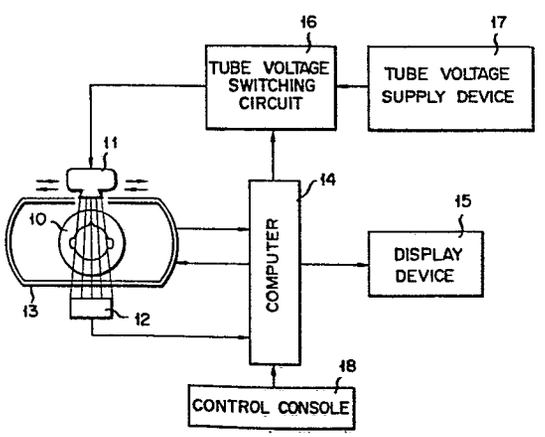
(54) Method and apparatus for collecting X-ray absorption data in X-ray computer tomographic apparatus.

(57) An X-ray tomographic apparatus, an X-ray tube (11) and an X-ray detector (12) arranged to face each other via a body (10) are caused to undergo reciprocation along a plane section of the body (10) for collecting X-ray absorption data of the plane section in a given angular aspect. Two different kinds of X-ray absorption data dependent upon respective different energy levels are collected on the basis of different tube voltages during the respective forward and return movements in one reciprocation. After one reciprocation, the X-ray tube (11) and X-ray detector (12) are rotated by a predetermined angle relative to the body (10). The reciprocation and rotation are alternately repeated to collect X-ray absorption data of the plane section of the body (10) in various angular aspects. The accuracy of the CT value can be increased using the two different kinds of X-ray absorption data during the forward and backward movements.

FIG. 5



EP 0 049 464 A1

Method and apparatus for collecting x-ray absorption data in x-ray computor tomographic apparatus

This invention relates to method and apparatus for collecting X-ray absorption data in X-ray computor tomographic apparatus, which can obtain precise X-ray absorption data with respect to a given plane section of a patient's body and also permits reconstitution of a high quality tomographic image.

Among X-ray tomographic apparatus, there are computorized tomographic scanners (hereinafter referred to as CT scanner).

One such CT scanner adopts a traverse and round system also called first generation. Fig. 1 shows this first generation. In this system, an X-ray tube XT and an X-ray detector DT are disposed to face each other via a patient's body P, and they are traversed together in the direction of arrows in Fig. 1, while the X-ray tube emitting X-rays along a plane section of the body P. The X-ray tube XT and the X-ray detector DT being so traversed, a radiation path XR is obtained which is parallel to the plane section of the body P. After one cycle of such scanning is ended, the angle of incidence of X-radiation on the plane section of the body P is changed. The linear motion and rotational motion are alternately repeated to collect X-ray absorption data usually over an angle range of 180 degrees. The

reconstitution of every point of the plane section of the body P is possible by permitting X-rays to be incident on the plane section substantially in all directions or angular aspects.

The X-ray absorption data obtained at the X-ray detector DT is analyzed in an electronic computor to calculate the X-ray absorption factor of individual points of the plane section. A tomographic image is reconstituted through the analysis of each point of the body's plane section on the basis of the determined X-ray absorption factor and with a graduation degree amounting to more than 2,000 steps. In addition to the first generation, there is another traverse and round system CT scanner called a second generation. As shown in Fig. 3, the second generation uses as the X-ray source an X-ray tube XT which generates X-rays in the form of sector having a small angle. An X-ray detector DT is disposed to face the X-ray tube XT via the body P mentioned above. The X-ray detector DT has a plurality of X-ray detecting elements arranged side by side. For the collection of X-ray absorption data, the X-ray tube XT and X-ray detector DT are traversed along a plane section of the body P and, after the completion of traverse scanning in each cycle, turned round by a predetermined angle.

As has been shown, either in the first or second generation the reconstitution of the final image involves image formation through conversion of the value of X-ray absorption that is determined by the structure of the inspected body into a corresponding shade signal. The X-ray absorption factor, i.e., the value of each piccell constituting the image, is referred to as CT value. This CT value is linearly related to the X-ray absorption factor and is called Hounsfield number after its inventor's name. This value corresponds to an absorption factor value based on an X-ray energy of 73 keV (hereinafter referred to as μ value). The

reconstitution of the final image is effected after deriving the CT value. However, the CT value is not an absolutely definite value for the following reasons. The X-radiation from the commercially available CT scanners usually does not consist of a single wavelength at the aforementioned reference energy level of 73 keV but has a spectral distribution. In addition, the X-ray absorption factor M of a predetermined structure of the body is not fixed because of variations of the proportions of the photoelectric effect and Compton effect. More specifically, the X-ray absorption in the neighborhood of a predetermined structure of the body varies depending upon whether or not the structure is surrounded by bones, and an energy spectrum shift, if any, causes a deviation of the CT value. The X-ray energy distribution which has the most significant influence upon the X-ray absorption value, can be known by varying the tube voltage of the X-ray tube.

Most of the existing CT scanners use only a single fixed tube voltage to achieve the linear scanning of a plane section of the body. It is therefore necessary to scan the same plane section two or more times, moving the X-ray tube and X-ray detector repeatedly and applying a different voltage on the X-ray tube during each linear scanning. This increases the exposure dose of X-rays and requires a longer time, inevitably causing the patient much trouble. In view of this the existing CT scanners cannot be said to be so practical.

It has been contemplated to provide a process of compensation for the shift of the CT value during the calculation for the image reconstitution. However, no correction method that is effective with any body and also for any inspecting condition has been found.

An object of this invention is to provide a method and an apparatus for collecting X-ray absorption data in an X-ray tomographic apparatus, in which the collection of X-ray absorption data with respect to a plane section

of the body is effected on the basis of different tube voltages during the respective forward and return movements of the X-ray tube and X-ray detector in a reciprocal scanning cycle so that the difference in the absorption value between the forward and return strokes of the scanning may be used for correcting the deviation of the CT value to thereby increase the accuracy of the CT value.

To attain this object, the method of collecting X-ray absorption data in an X-ray computor tomographic apparatus according to the invention comprises a step of collecting X-ray absorption data of a given plane section of a body being inspected, said X-ray tube being disposed to face an X-ray detector via said body and being traversed together with the X-ray detector along the plane section of the body, with respect to X-rays emitted from the X-ray tube on the basis of a predetermined tube voltage during a forward traverse of the X-ray tube and X-ray detector, a step of altering the tube voltage after the completion of the step of collecting X-ray absorption data during the forward traverse, a step of collecting X-ray absorption data of the plane section of the body with respect to X-rays emitted from the X-ray tube on the basis of the altered tube voltage during a return traverse of the X-ray tube and X-ray detector, and a step of rotating the body about the center thereof by a predetermined angle relative to the X-ray tube and X-ray detector after the completion of X-ray absorption data in one reciprocation of the X-ray tube and X-ray detector, the step of collecting X-ray absorption data with one reciprocation of the X-ray tube and X-ray detector and the subsequent step of rotating the body by the predetermined angle relative to the X-ray tube and X-ray detector being repeated at least over a rotational angle range of 180 degrees to thereby obtain X-ray absorption data of the plane section of the body in different angular

aspects.

Also, the apparatus for collecting X-ray absorption data in an X-ray computor tomographic apparatus according to the invention comprises computor means for effecting operations of at least supplying a scanning start signal to an X-ray tube and also to an X-ray detector, receiving a signal indicative of the direction of scanning of the X-ray tube and X-ray detector, generating a tube voltage switching instruction signal at the time of changing the scanning direction, receiving X-ray absorption data detected by the X-ray detector during the forward and return traverses of scanning and also providing an image constitution output to a display unit and also generating energy-dependent diagnosis data from the two different energy data obtained during the forward and return traverses of scanning respectively, means connected to the X-ray tube for supplying a tube voltage thereto, and tube voltage switching control means connected between the X-ray tube and the tube voltage supplying means for controlling the switching of different tube voltages for the respective forward and return traverses in the reciprocal scanning of the X-ray tube and X-ray detector according to a tube voltage switching instruction signal received from the computor means.

With the above method and apparatus for collecting X-ray absorption data in an X-ray computor tomographic apparatus according to the invention, two different kinds of X-ray absorption data with respect to a given plane section of the body which are respectively based on the two different tube voltages, can be collected in a short period of time, and a highly accurate image with the CT value close to the characteristics of the structure of the body can be obtained from three different kinds of X-ray absorption data, namely two based upon the two different tube voltage and the last one as the difference between these two different data.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a view useful to explain the scanning operation of a prior art first generation CT scanner;

Fig. 2 is a view useful to explain the rotational operation of the prior art CT scanner shown in Fig. 1;

Fig. 3 is a view useful to explain the traverse operation of a prior art second generation CT scanner;

Fig. 4 is a view showing the orbit of motion of X-ray tube and useful to illustrate the method of collecting X-ray absorption data according to the invention;

Fig. 5 is a block diagram, partly in schematic, outlining an X-ray absorption data collection apparatus in an X-ray tomographic apparatus according to the invention; and

Fig. 6 is a block diagram illustrating the function of a computor shown in Fig. 5.

Now, an embodiment of the invention will be described with reference to Figs. 4, 5 and 6.

The invention is applied to a first generation and a second generation CT scanner. Fig. 4 shows the orbit of movement of an X-ray tube and an X-ray detector disposed to face each other via a body.

The X-ray tube and X-ray detector which are located at a position a is linearly traversed forward to scan the body P with the X-ray tube emitting X-rays on the basis of a predetermined tube voltage, for instance 100 kV. In the backward or return traverse, the X-ray detector detects X-ray absorption data in a plane section of the body P in a given angular aspect. When the X-ray tube reaches a point b, its voltage is switched to, for instance, 140 kV. Then, the X-ray tube and X-ray detector return to the point c. During their return traverse, X-ray absorption data is obtained on the basis of a different tube voltage from that during the forward

traverse. Thus, two different kinds of X-ray absorption data are obtained with respect to the same plane section. Then, the X-ray tube and X-ray detector at the point c are rotated by a predetermined angle to a point d. When the point d is reached, the X-ray tube voltage is again switched to the aforementioned predetermined voltage again, and during the subsequent forward traverse up to the point c X-ray absorption data is detected with respect to the X-rays that are emitted from the X-ray tube toward the body P on the basis of the aforementioned predetermined tube voltage. Upon reaching of the point c, the tube voltage is switched once again, and X-ray absorption data is detected on the basis of the different tube voltage from that during the forward traverse until the X-ray tube and X-ray detector arrive at a point f. The sequence of linear motion and rotational motion as mentioned are repeated, and the detection of X-ray absorption data with respect to a given plane section is ended with the completion of 180-degree rotation.

The detection or collection of data on the basis of two different tube voltages, one during the forward traverse and the other during the return traverse in the translational reciprocal scanning, permits obtaining three different images, namely two images based on the respective tube voltages during the forward and return traverses and an image obtained by correction with the difference between the X-ray absorptions based on the two different tube voltages. Thus, an image having at CT value close to the structure of the body can be obtained. Particularly, it is possible to make analysis of the X-rays' electron density and the structural element composition of the body from the aforementioned X-ray absorption difference data.

Now, an X-ray absorption data collection apparatus according to the invention will be described with reference to Fig. 5.

An X-ray tube 11 and an X-ray detector 12 are supported by a frame 13 such that they face each other via a body 10. The X-ray tube 11 and X-ray detector 12 are capable of both linear motion and rotational motion with respect to the body 10.

A start instruction to start the scanning of the X-ray tube and X-ray detector 12, a scanning speed switching instruction and/or a slice width switching instruction are supplied as control instruction signal A from a computor 14 to the CT scanner.

The aforementioned two different X-ray absorption data based on the different tube voltages, detected by the X-ray detector 12, are coupled as data detection signal B to the computor 14. In the computor 14, the data detection signal B is analyzed for display of reconstitution image on a display unit 15 at a graduation degree corresponding to X-ray absorption factor at each point of the plane section.

A signal C which indicates whether the X-ray tube 11 and X-ray detector 12 are in their forward or return travel is also coupled to the computor 14. A tube voltage supply device 17 is connected through a tube voltage switching circuit 17 to the X-ray tube 11. The tube voltage switching circuit 16 is connected to the computor 14. When the computor 14 detects the end of the forward or return traverse from the aforementioned signal C from the CT scanner, it supplied a control signal to the tube voltage switching circuit 16 to switch the tube voltage supplied from the tube voltage supply device 17 to the X-ray tube 11. The setting of the computor 14 in accordance with the system condition of the CT scanner is done from a control console 18. The function of the computor 14 will now be described with reference to a block diagram of Fig. 6.

A scanning control circuit 21 generates the instruction signal A supplied to the CT scanner according to an instruction signal from a CT monitor 20. A

scanning monitor 22 detects the aforementioned signal C from the CT scanner, indicating the state of motion of the X-ray tube 11 and X-ray detector 12, and reports the detection to the CT monitor 20. After confirming the scanning state of the CT scanner, the CT monitor 20 gives an instruction to an X-ray control circuit 23 to let the control circuit 23 supply a control signal to the tube voltage switching circuit 16 mentioned above according to the detected scanning state. A data collection and correction calculation circuit 24 collects the X-ray detection data signal B corresponding to the affected part of the body 10, detected by the X-ray detector 12 mentioned above, and effects correction calculation with the detection data signal B in accordance with an instruction supplied from the CT monitor 20. The result of calculation is stored in a data memory 25. A reconstitution processing circuit 26 receives the stored data output from the data memory 25 and an instruction output from the CT monitor 20 and reconstitute the X-ray detection data. The reconstitution data is stored in a reconstitution image memory 27. An image display output circuit 28 receives the stored data from the reconstitution image memory 27 and an instruction signal from the CT monitor 20 and supplies an image display output to the image display unit 15 mentioned above for display. An image recording/reproducing circuit 29 receives the stored data from the reconstitution image memory 27 and an instruction signal from the CT monitor 20 and can let the received reconstitution image be stored on a magnetic tape 30 or on a flopply disc 31.

The CT monitor 20 is connected through a conversation operation circuit 32 to the console 18 mentioned above. The conversation operation circuit 32 can set the operation procedure depending upon the condition of the CT system under the control of an instruction signal from the control console 18.

Claims:

1. A method of collecting X-ray absorption data in an X-ray computor tomographic apparatus, comprising a first step of collecting X-ray absorption data of a given plane section by moving together an X-ray tube and an X-ray detector disposed to face said X-ray tube and a second step of rotating said body relative to said X-ray tube and X-ray detector by a predetermined angle upon completion of the movement of said X-ray tube and X-ray detector, c h a r a c t e r i z e d in that said first step is to repeatedly move said X-ray tube and X-ray detector back and forth and to collect two kinds of X-ray absorption data, one produced by applying a voltage on said X-ray tube while said X-ray tube and X-ray detector are moving forward and the other produced by applying a different voltage on said X-ray tube while said X-ray tube and X-ray detector are moved backward, and that said second step is carried out upon completion of every reciprocatory movement of said X-ray tube and X-ray detector and is repeated until said body is rotated relative to said X-ray tube and X-ray detector through at least 180°.

2. An apparatus for collecting X-ray absorption data in an X-ray computor tomographic apparatus, comprising:

computer means for effecting at least operations of supplying a scanning start signal to an X-ray tube and an X-ray detector, receiving a signal indicative of the direction in which said X-ray tube and X-ray detector are moving, generating a tube voltage switching instruction signal at the change of the direction in which said X-ray tube and X-ray detector are moving, receiving X-ray absorption data detected by said X-ray detector while said X-ray tube and X-ray detector are moving foreard and backward and providing an image-forming output to a display unit and also generating

energy-dependent diagnosis data from two kinds of energy data obtained while said X-ray tube and X-ray detector are moving forward and backward;

means connected to said X-ray tube for supplying a tube voltage to said X-ray tube; and

tube voltage switching control means connected between said X-ray tube and said tube voltage supplying means for controlling the switching of different two voltages, one to be applied on said X-ray tube while said X-ray tube and X-ray detector are moving forward and the other to be applied on said X-ray tube while said X-ray tube and X-ray detector are moving backward, according to a tube voltage switching instruction signal supplied from said computor means.

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FIG. 1

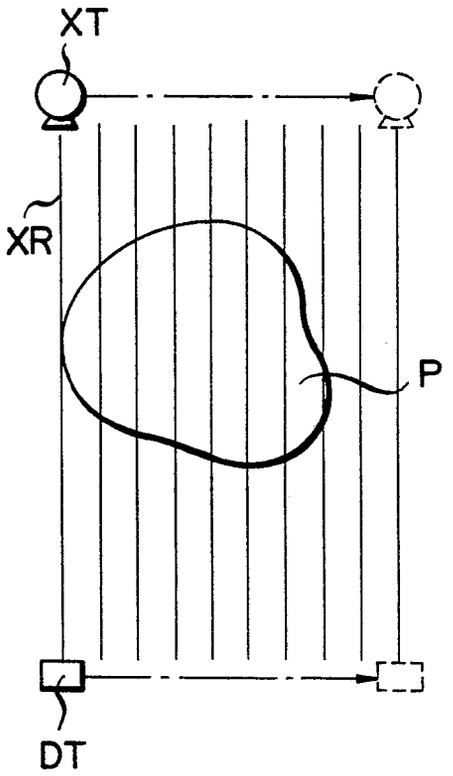

FIG. 2

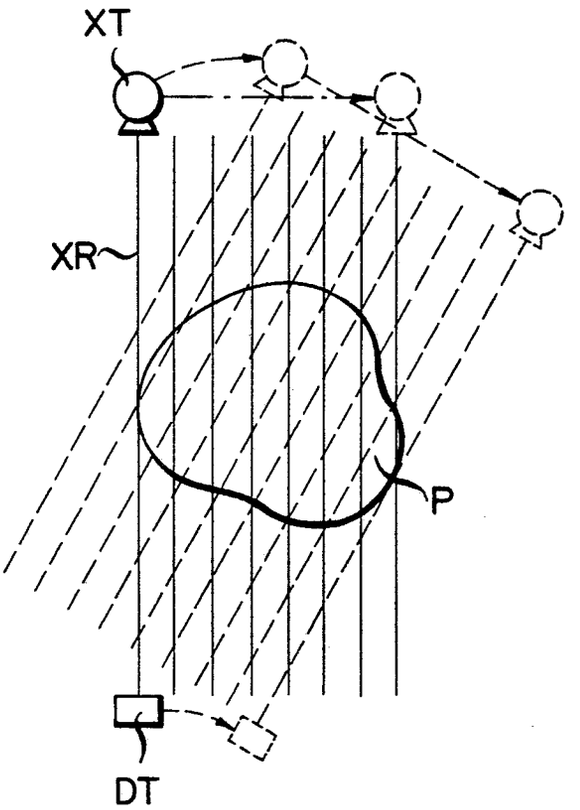

FIG. 3
(PRIOR ART)

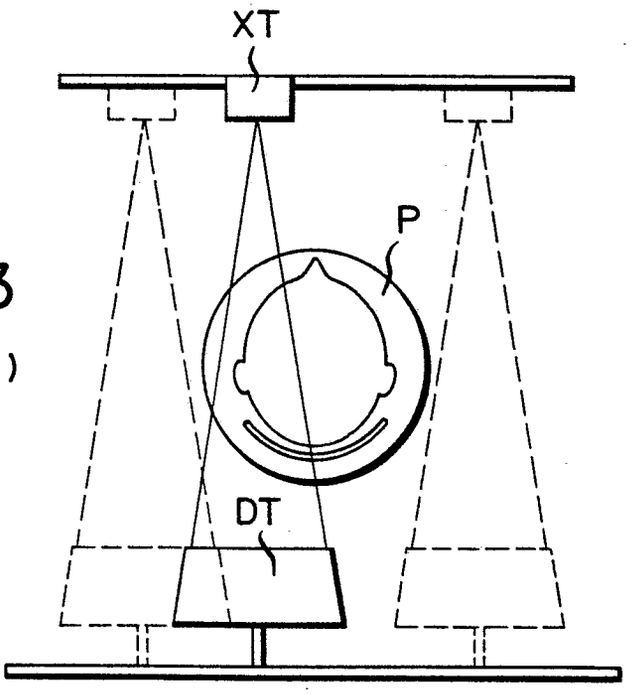

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FIG. 4

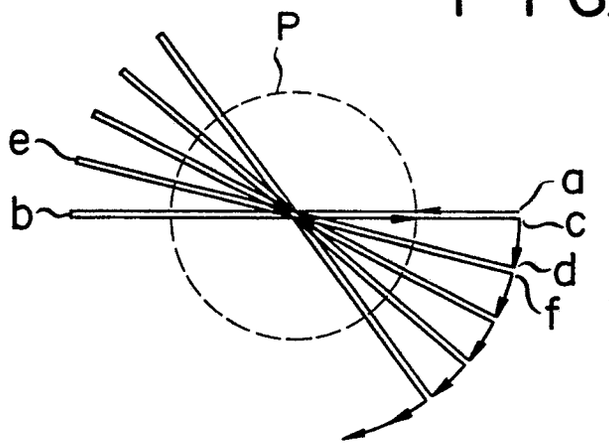

FIG. 5

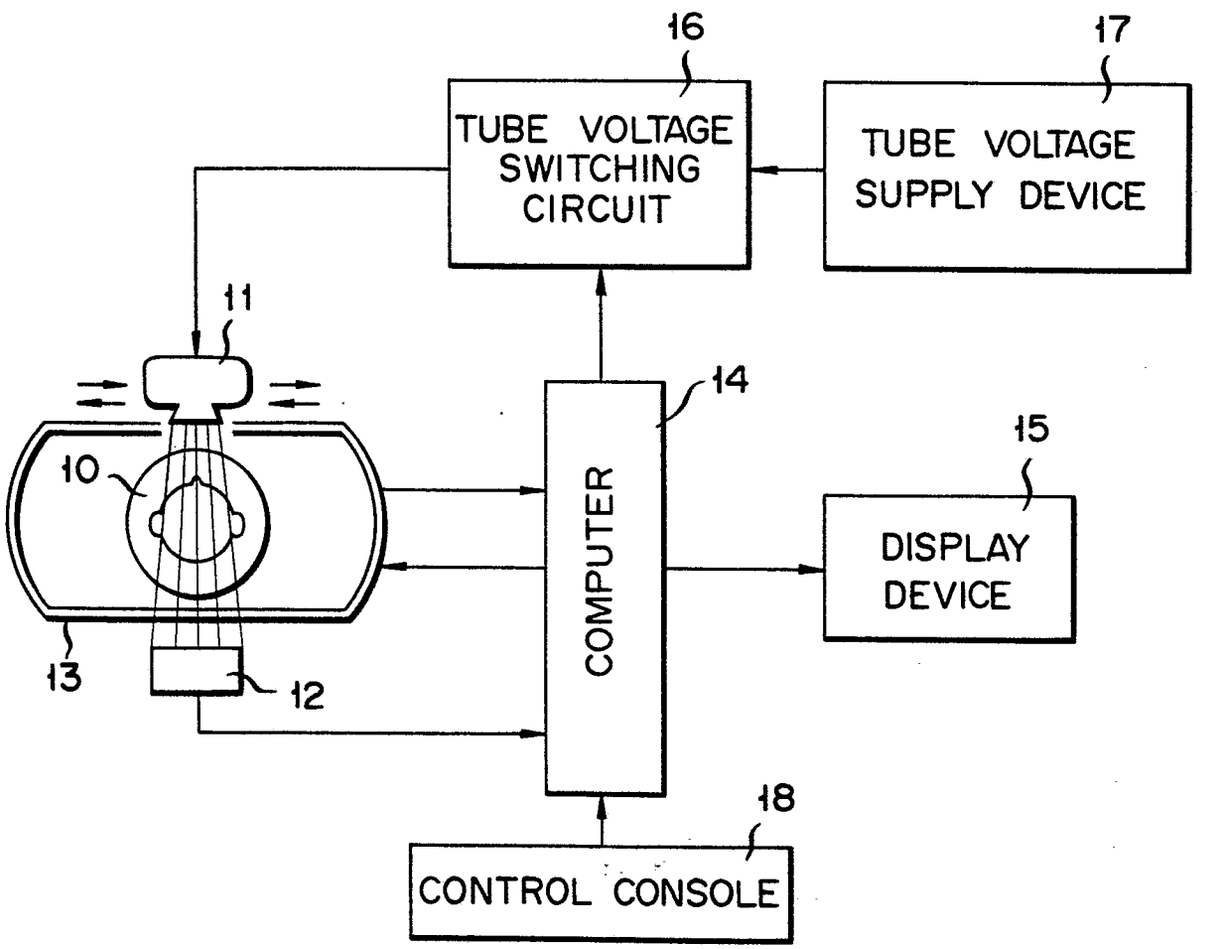

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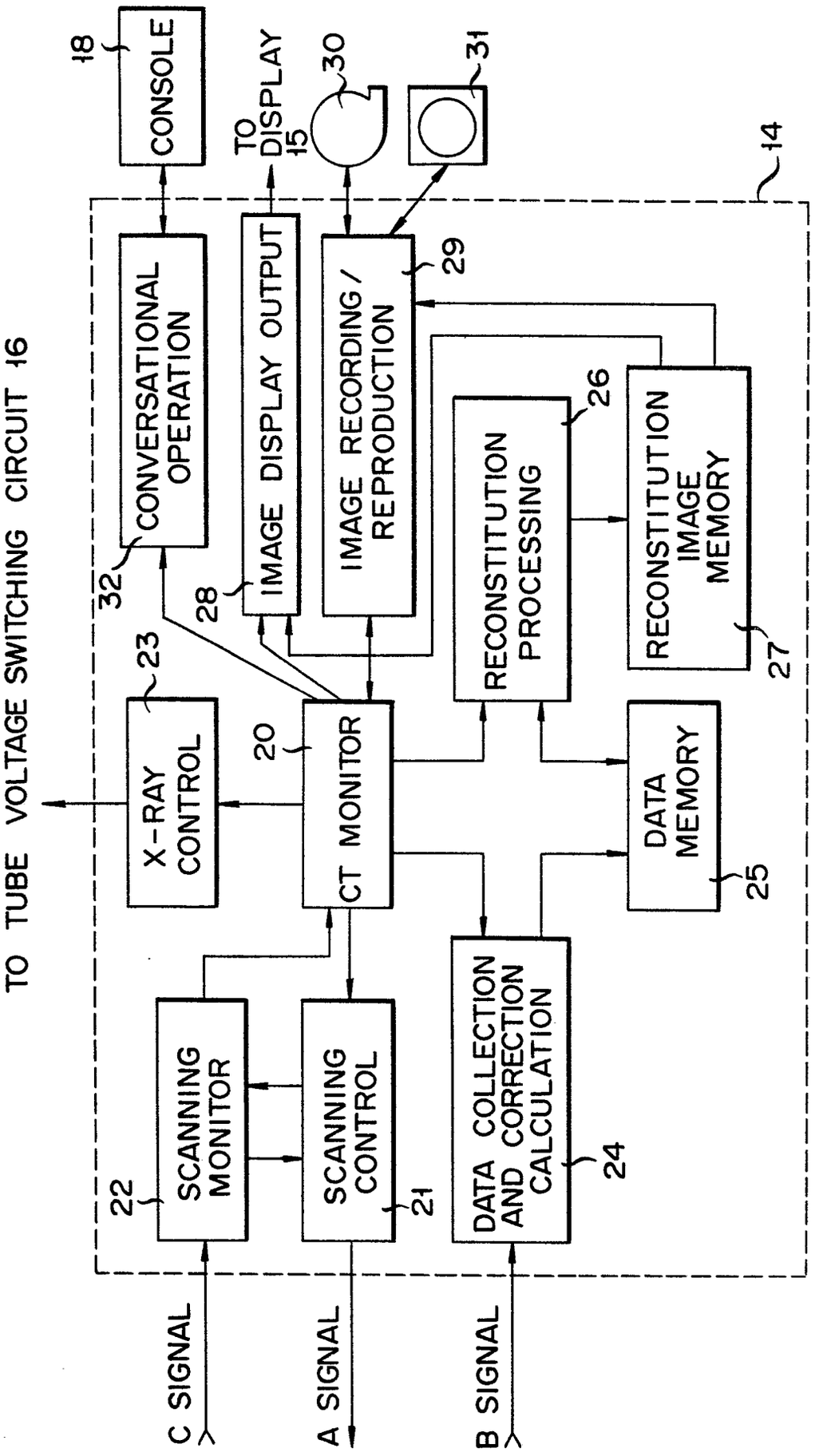
FIG. 6



European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 81 10 7746

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	A 61 B 6/02
	US - A - 4 029 963 (R.E. ALVAREZ et al./THE BOARD OF TRUSTEES OF LELAND STANFORD JUNIOR UNIVERSITY) * abstract; column 2, line 62 - column 3, line 4; column 5; lines 52-68; column 8, lines 2-40; column 9, lines 4-54; figures 1-4 * --	1	
	US - A - 3 971 948 (M.PFEILER et al./SIEMENS AG.) * abstract; column 3, lines 4-23; column 3, line 37 - column 4, line 53; figures 1,2 * --	1,2	TECHNICAL FIELDS SEARCHED (Int.Cl. 3) A 61 B 6/02
	US - A - 4 149 081 (E.J. SEPPI/ VARIAN ASSOCIATES INC.) * abstract; column 2, lines 9-29; column 6, line 62 - column 8, line 2; figures 2a-2c * --	1	
P	DE - A - 2 950 780 (SIEMENS AG.) * page 4, line 8 - page 5, line 15; page 5, line 34 - page 7, line 13; figures * ----	1,2	CATEGORY OF CITED DOCUMENTS X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons &: member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	15-01-1982	RIEB

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